

# CO<sub>2</sub> emission from two old mine drillings (Mt. Amiata, Central Italy) as a possible example of storage and leakage of deep-seated CO<sub>2</sub>.

Barbara Nisi (1), Orlando Vaselli (2),(3), Javier de Elío(4),(5), Marcelo Ortega(5), Juan Caballero(5), Franco Tassi(2),(3), Daniele RAPPUOLI (6), Luis FELIPE MAZADIEGO(4)

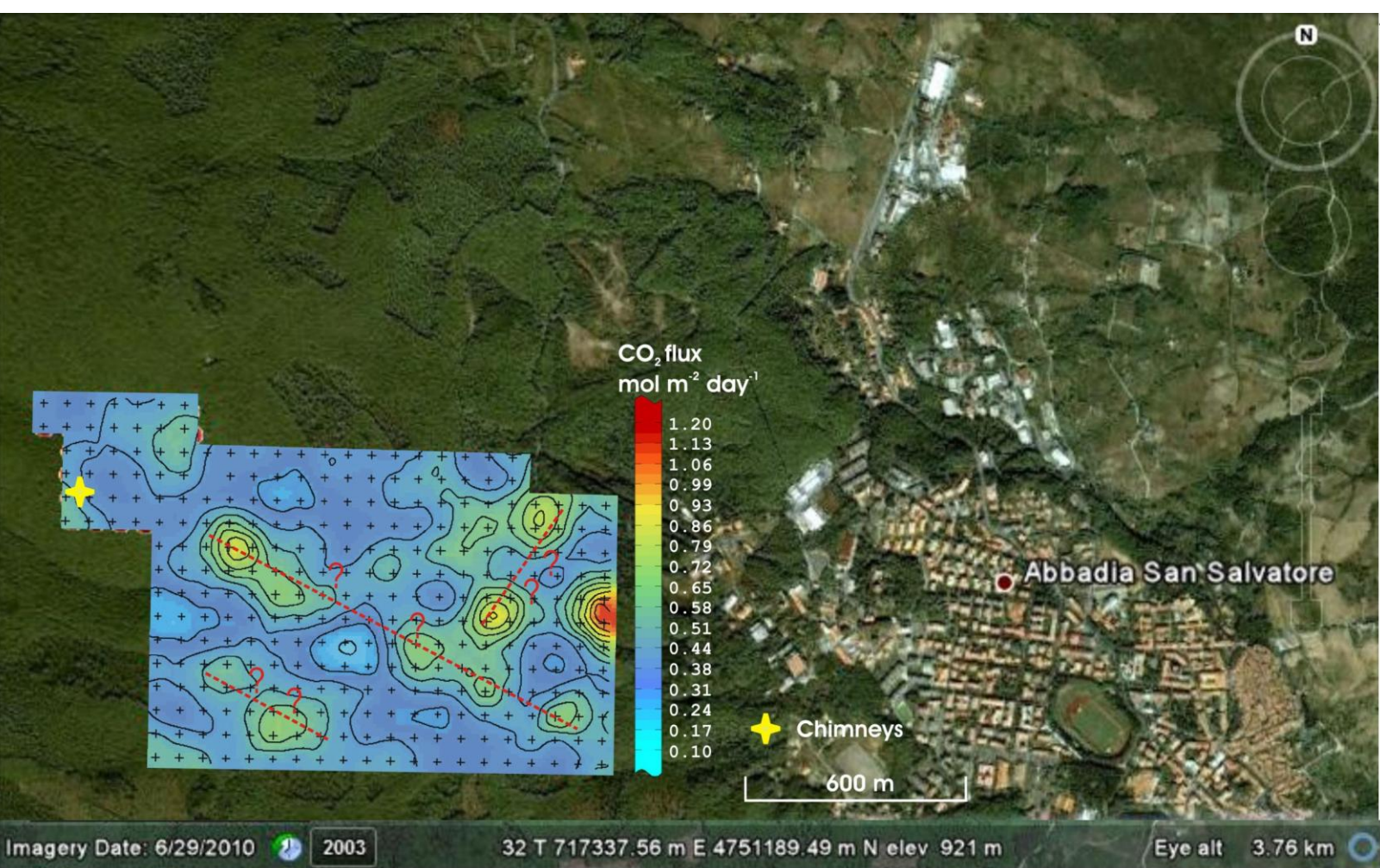
(1) CNR-IGG Institute of Geosciences and Earth Resources, Pisa, Italy ; (2) Department of Earth Sciences, Florence, Italy; (3) CNR-IGG Institute of Geosciences and Earth Resources, Florence, Italy; (4) Fundación Ciudad de la Energía, Ponferrada, Leon, Spain; (5) ETS Ingenieros de Minas, Universidad Politécnica de Madrid, Spain, (6) Union of Municipalities Amiata-Val d'Orcia, Gallina, Castiglion d'Orcia, Siena, Italy

The Mt. Amiata area (southern Tuscany, central Italy) is characterized by a volcanic activity that lasted ca. 100,000 years, the related deposits being emplaced between 300 and 200 ka. Presently, the “residual” volcanic activity of this edifice, deriving from the emplacement of a magmatic body in the Pliocene, is likely related to the presence of two geothermal systems exploited for the production of electrical energy and to the numerous CO<sub>2</sub>-rich gas manifestations and Ca-SO<sub>4</sub>-rich thermo-mineral water discharges mainly seeping out in NE and SW sector of Mt. Amiata (Fig. 1). The Mt. Amiata geothermal area is located in an extended continental crust, where extensional structures developed from the Middle Miocene to the Quaternary, whilst collisional structures occurred from the Cretaceous to the Early Miocene. The observed high heat flow is due to this magmatic body which is located about 6–7 km below sea-level and not completely cooled down. The volcanic products are mainly constituted by trachydacitic rocks. In the past Mt. Amiata was one of the biggest producers of Hg in the world. The Mt. Amiata Hg district is mainly distributed in the central-eastern part of this silicic volcanic complex, although the principal mining activity was located in the municipality of Abbadia San Salvatore. The extraction and metallurgy of cinnabar (HgS) was aimed to produce metallic mercury from historic times until the middle ‘70s when most of the mercury mines in the world were shut down due to environmental concerns. In the Abbadia San Salvatore area several wells were drilled for mining exploration in the second half of the last century. During these investigations in two drillings (namely, Acquapassante and Ermeta, respectively), a CO<sub>2</sub>-rich gas fertile horizon was intercepted. Presently Acquapassante and Ermeta represent an important emission source of CO<sub>2</sub> (Fig. 2), i.e. 127 and 819 m<sup>3</sup>/h, respectively. The recent increased concern of global greenhouse gas emissions has represented a strong impulse for the municipality of Abbadia San Salvatore to propose alternative strategies to limit the introduction of CO<sub>2</sub> and H<sub>2</sub>S into the atmosphere.

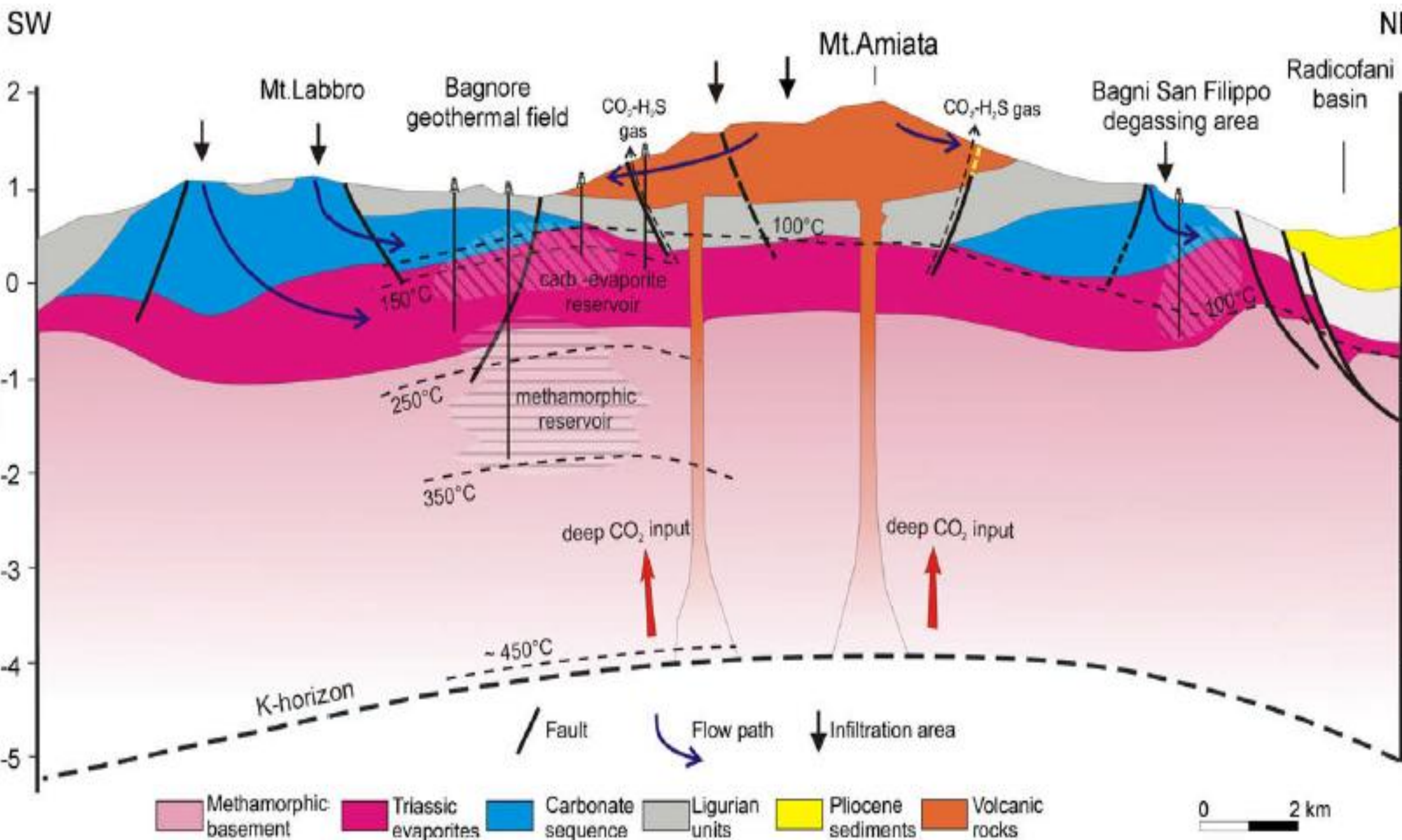


**Fig. 2.** Acquapassante (a) and Ermeta (b) chimneys

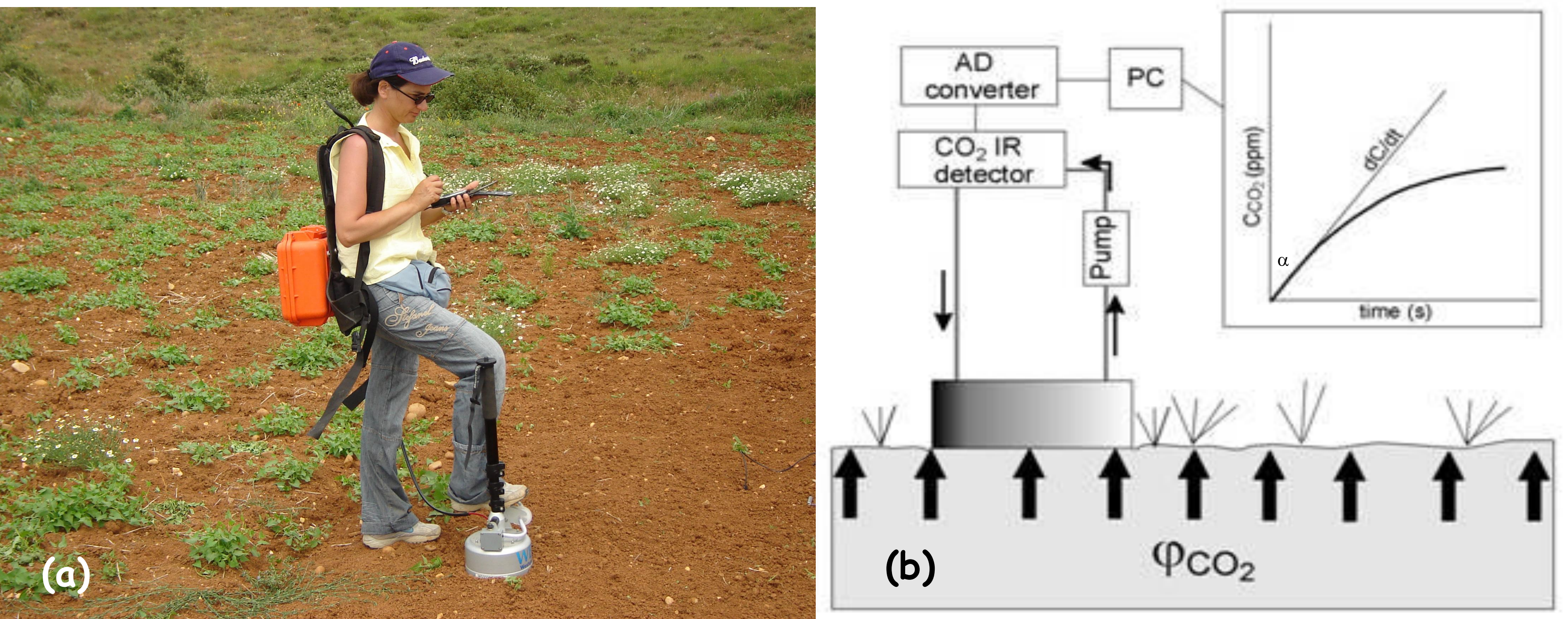
The present framework describes the methodological approach used for the determination of the CO<sub>2</sub> flux ( $\phi\text{CO}_2$ ) from the soil in the Ermeta areas in order to evaluate the total output of CO<sub>2</sub> diffuse degassing from the soil and to better constraint the real necessity to shut down the chimney to reduce the CO<sub>2</sub> emission. The technique used in this study is a direct and dynamic method for measuring  $\phi\text{CO}_2$  from any soil following the principle of the so-called accumulation chamber (Fig. 3 a and b). This method allows the determination of the increasing rate in CO<sub>2</sub> concentrations within an inverted accumulation chamber placed on the soil surface (Fig.3 a), as the soil gas is pumped through specific detectors (IR). An appropriate software package gives the operator the evaluation of the initial slope of the CO<sub>2</sub> vs. time line, which is carried out directly in the field. The initial slope is proportional to CO<sub>2</sub> flux from soil. It is a rapid measurement that takes nearly 1 minute (Fig. 3 b). To have a good flux estimation the correct interval of the flux curve has to be selected. A linear best fit interpolation of the flux curve in the interval is computed, in order to evaluate the coefficient “ $\alpha$ ”.



**Fig. 5.** Map of CO<sub>2</sub> soil flux (in mol m-2 day-1) for the area of the Ermeta chimney. Red dash lines are referred to preferential alignments of the highest CO<sub>2</sub> flux values.



**Fig. 1.** NE-SW geological cross-section through the Monte Amiata complex, with the two reservoirs of the geothermal system in evidence



**Fig. 3.** Technique used in this study for measuring  $\phi\text{CO}_2$  from soil (Fig. 3 a and b).

The campaign, carried out in July 2011, covered an area of 653,550 m<sup>2</sup> with 302 evenly distributed measuring sites (Fig. 4). The measured CO<sub>2</sub> fluxes ranged from 0.07 to 3.42 mol m<sup>-2</sup> day<sup>-1</sup>, with an average value of 0.38 mol m<sup>-2</sup> day<sup>-1</sup>.



**Fig. 4.** Sampling grid carried out in July 2011

The isoflux map shows that the diffuse CO<sub>2</sub> flux is generally low (average value of 0.38 mol m<sup>-2</sup> day<sup>-1</sup>), although values >0.6 and up to 3.42 mol m<sup>-2</sup> day<sup>-1</sup> were occasionally measured at NW and SW and E, respectively, of the studied area (Fig.5). The total CO<sub>2</sub> output for the Ermeta area was calculated by using the Sichel’s *t*-estimator (*M*). The total soil CO<sub>2</sub> output for each population is calculated by multiplying *M* times the area covered by each population. In the same way, the central 95% confidence intervals of the total CO<sub>2</sub> output are used to calculate the uncertainty of each population. According to Sichel’s *t*-estimator (*M*) the total amount of CO<sub>2</sub> released through diffuse degassing is estimated to be 11.81 ± 1 tons/day. The direct survey of CO<sub>2</sub> soil flux has indicated the presence of possible fractures/faults from where higher amounts of CO<sub>2</sub> can be released, suggesting the importance of this methodological approach in geological studies not only associated to CCS projects.